Earth-Space Propagation Data Bases

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Abstract

This paper, designed for the newcomer rather than the expert, will take a rather broad view of what is meant by "propagation data bases" in that it will take the term to mean both the actual measurements and models of earth-space paths. The text will largely be drawn from CCIR Reports of Study Group 5, now annexed to Recommendations of ITU-R Study Group 3, plus some experience with a course taught at the Unversity of Colorado.

Introduction

As the first JPL Manager for the NASA Propagation Program my interest was aroused by the announcement of its 20th NAPEX meeting (NAPEX derives from NASA Propagation EXperiminters). This paper came about when I called up Dr. Nasser Golshan, the new manager of the NASA Propagation Program at JPL, and offered to present a paper at NAPEX XX on the history of NAPEX. Nasser countered with the suggestion that I do a paper on earth-space propagation data bases, particularly aimed at the newcomer. With some trepidation I agreed to do this.

A little bit of history. I first got involved in the NASA Propagation Program in 1980 when JPL was offered the operational management of the program, and I became its first JPL manager. In 1981 Professor Warren L. Flock of the EE Department at the University of Colorado came to spend a sabbatical year with me at JPL and the idea was conceived of a handbook to parallel Dr. Louis J. Ippolito's famous text Propagation Effects Handbook for Satellite Systems Design - A Summary of Propagation Impairments on 10 to 100 GHz Satellite Links with Techniques for System Design," 4th edition] 989. NASA Reference Publication 1082-04. 1 suggested to Warren that he prepare a companion handbook, so, in order to be complementary, his text was titled "Propagation Effects on Satellite Systems at Frequencies below 10 GHz - A Handbook for Satellite System Design" NASA Reference Publication 1108, first issued in December 1983, 2nd Edition 1987 (as NASA RP 1108-02). When he returned to the University of Colorado, Warren developed a course, ECEN 5264 "Propagation Effect on Satellite Communications, " using his NASA RP 1108 as the text. I inherited this course from Warren shortly after I joined the University of Colorado in 1987 after retiring from JPL. I enlisted the help of Dr. David C. Hogg and the two of us have offered the course every one or two years since then.

Initially in the course we used Warren's NASA Reference Publication 1108 (02) and Radiowave Propagation by Lucien Boithias (McGraw Hill 1987) as texts, supplemented by CCIR material. In 1989 when two volumes published by Peter Perigrinus for the IEE: Satellite -to-Ground Radiowave Propagation by Dr. Jeremy Allnutt and Ionospheric Radio by Dr. Kenneth Davies, we substituted those volumes for Boithias.

I first become involved in the CCIR, the International Radio Consultative Committee of the international Telecommunications Union (ITU), in the late fifties (I became vice chairman of Study Group 6 in 1959 but since 1976 have been principally involve with Study Group 5) so I am comfortable inducting CCIR material in my work.

A discussion of pertinent international organizations is given in the first part of this paper with emphasis on the CCIR/ITU-R. This is followed by a discussion of some of the problems encountered in worldwide models used in the preparation of propagation link budgets, plus a bit on a site-specific-model. The intent is o provide the novice engineer with the information to get started in he field.

National and international organizations.

I have tried to be active in three national or international" organizations in my professional career: the IEEE, the URSI, and the CCIR (now renamed the ITU-R). I have been involved in radiowave propagation since 1944.

The **Institute of Electrical and Electronic Engineers (IEEE),** is the world's largest professional organization, now organized in 35 specialized Societies, one of which is the Antennas and Propagation Society, abbreviated AP/S. This Society puts out two publication: the IEEE Transactions on Antennas and Propagation and the IEEE Antennas and Propagation Magazine. The Transaction of AP/S is a highly-rated professional journal for researh papers, while the AP/S

Magazine is more informal. I am the propagation editor for the Magazine. The IEEE Home Page is found on the World Wide Web at URL:http://www.ieee.org, or the organization can be accessed by telephone at 1 -800 -678 -IEEE.

The **International Union of Radio Science (URSI)** was created in 1919, has just under 40 member countries, and is one of the earliest members of the International Council of Scientific Unions (ICSU). In the United States, the affiliating organization is the National Academy of Sciences. URSI is headquartered in Brussels. It holds a Genera] Assembly every three years, most recently in Kyoto in 1993, to be followed by the XXVth General Assembly in Line, France August 28 to Sept. 5,1996.

URSI's work is organized in 10 Commissions. Commission F "Wave Propagation and Remote Sensing" (chaired by Prof. R.K. Moore of Kansas State University) has traditionally dealt with radio propagation through non-ionized media, and Commission G "Ionospheric Radio and Propagation" (chaired by Prof. K.C. Yeh of the University of Illinois) has traditionally dealt with propagation through ionized media. In America the United States National Committee of URSI, supported by the National Research Council holds a meeting of all Commissions once a year - in recent years in January in Boulder hosted by the University of Colorado and a summer meeting joint with the IEEE Antennas and Propagation Society in which not all Commissions participate. Through arrangement with the American Geophysical Union, URSI is supported by the periodical Radio Science. The participants in URSI are largely academics and research scientists.

The International Radio Consultative Committee (CCIR) was organized in 1927. In 1932 it became the technical radio advisory body of the newly consolidated International Telecommunications Union (ITU). Following the formation of the United Nations (UN) in 1945 the ITU became a Specialized Agency of the UN. The work of the CCIR has been carried out up to 1994 through twelve Study Groups, two of which, Study Group V (Propagation in Non-Ionized Media) and Study Group VI (Propagation in Ionized Media) deal with applied propagation problems.

Membership in the ITU (and CCIR) is by administrations (e.g., the U. S., Canada, the U. K.) established by treaty. Hence, U.S. participation in the work of the CCIR is through the U.S. Department of State.

In April 1993, following a reorganization of the ITU, the name CCIR disappeared to be replaced by the initials JTU-R (R for Radiocommunications). Simultaneously, the two propagation Study Groups were consolidated into Study Group III. The international Chairman of Study Group 111 is Leslie Barclay of the U.K. The chairman of U.S. Study Group III is Eldon Haakinson (eldon@its.bldrdoc.gov) at the Institute for Telecommunication Sciences in Boulder. The CCIR held Plenary Assemblies every four years and published their most recent texts as Recommendations and Reports. The Reports, last published in 1990 were well referenced. Now ITU-R only publishes Recommendations (no references), and a great deal of the value has been lost. CCIR and ITU-R volumes can be obtained directly from the ITU in Geneva, or from the National Technical Information Service.

CCIR SG5 & 6/ITU-R SG3

The chairman of the new Study Group 3 is Leslie W. Barclay of the U.K. The most recent version of these texts has the N and I in the title removed, but the only version that I have (1994 PN Series) still has these letters in them so I have retained the N and I. The principal texts of the former CCIR Study Groups 5 and 6, now the new ITU-R Commission 3, as they relate to Earth-Space Propagation are:

Recommendation ITU-R PN.618-3 ***Propagation Data and Prediction Methods Required for the Design of Earth-Space Telecommunication Systems***

This text is derived from the former Study Group 5 text Report 564-4 (1990) of the same title. It is the ITU-R model for Earth-space propagation even though it does not contain any ionospheric data.

Recommendation ITU-R PI.531 ***Ionospheric Effects upon Earth-Space Propagation***

This text, derived from the former CCIR Report 263-6 (1 990), is the definitive text on ionospheric effects on earth-space systems. The ionospheric tables included in each of the former Study Group 5 texts below relating to specific services are all derived from the former Tables VII and VIII of Report 263-6.

Recommendation ITU-R PN.679-1 ***Propagation Data required for the Design of Broadcast-Sate llite Systems***

This text is an attenuated version of CCIR Report 565-4 (1 990).

Recommendation ITU-R PN.680-1 ***Propagation Data Required for the Design of Earth-Space Maritime Mobile Telecommunication Systems***
This Text is drawn from CCIR Report 884-2 (1990).

Recommendation ITU-R PN.681-1 ***Propagation Data Required for the Design of Earth-Space Land-Mobile Telecommunication Systems***
This text has its roots in CCIR Report 1009-1 (1 990) but has been completely rewritten.

Recommendation ITU-R PN.682-1 ***Propagation Data Required for the Design of Earth-Space Aeronautical-Mobile Telecommunication Systems***
This text is derived from CCIR Report 1148 (1990).

Unfortunately, the removal of references from the published ITU-R texts makes it almost impossible to track the origin of the material in these texts unless one is privy to the unpublished Study Group documents. However a recent memo from Eldon Haakinson indicates that these working documents of Study Group 3 may be available on the Internet.

ITU Web Site: http: //www.itu.ch
look for: ITU Radiocommunication Sector
click on: Study Group 3

Data banks are treated in the next text.

Recommendation ITU-R PN.311-7 ***Acquisition, Presentation and Analysis of Data in Studies of Tropospheric Propagation*** traces its origins back to 1953. The most recent version that I have had access to came out in 1994. As mentioned above, the new designation in 1996 has deleted the N so that the above would now be listed as Rec. ITU-R P 311-7.

The Introduction to the Recommendation contains the following wording:
"One of the essential requirements for the provision of reliable methods for prediction of radio propagation effects is the establishment of suitable computer data banks. Such data banks must:

contain all data available that are of adequate standard,

- be widely accepted as the source material on which to conduct testing,
- be readily available.

It is a principle of the data banks that they shall contain only such data as may be used for:

testing prediction methods recommended by Radiocommunication Study Group 3 (and may of course be used to test other methods): and

- for the creating and updating of radiometeorotogical maps relevant to the prediction of radio propagation effects."

Data banks are treated in section 5 in the following categories:

Part I	Terrestrial line-of-sight path data
Part 11	Earth-space path data
Part 111	Terrestrial trans-horizon path and rain-scatter data
Part IV	Radiometeorological data
Part V	Terrestrial broadcasting data
Part VI	Data for mobile satellite services

The actual work of running the data bank has been undertaken by Bertram Arbesser-Rastburg at ESSA-ESTEC at Noordwijk in The Netherlands (bertram@estec.esa.nl). Copies of the data base may be obtained on 3.5 inch DOS disks for 100 Swiss Francs from:

Study Group Department "B", Radiowave Propagation
Attn: Dr. Kevin Hughes
Place Des Nations
CH-1211 Geneva 20
Switzerland

Bertram, through the good offices of Eldon Haakinson, provided me with a copy of the data base. It contains a vast array of data but is probably more useful to the specialist than the newcomer.

Other data in regional and specialized data banks which may or may not have submitted their measurements in response. to Rec ITU-R PN.311 -7 exist around the world. For Example:

Wolf Vogel: ACTS satellite data
Robert K. Crane: Rain and scintillation data
ESA ESTEC: Data from ESA COST Programs:
Aldo Paraboni: ITALSAT Data

Earth-Space Propagation Modeling

Compact introductory information may be found in recent handbooks (e.g., Smith 1995a, b). Thorough descriptions of the factors entering propagation modeling is found in the NASA Propagation Handbooks

(Ippolito 1989, Flock 1987). Several good texts on Earth-space propagation are Allnutt (1989), Ippolito (1986), and Pratt and Bostian (1 986). Fine texts on satellite communications are (Roddy 1989), Miya (1975), Morgan and Gordon 1989, and Rees (1990), to name a few.

The JPL Computer Model. Computer models prepared at JPL have been described by Anil Kantak, Krisjani Suwitra and Choung Le (1993,1994,1995). A presentation and demonstration is scheduled after the break at this meeting. While incorporating many different options the one used for past demonstrations has been the CCIR method. It has the advantage of simplicity and international acceptability.

The method illustrated makes use of world maps of rain rate exceeded 0.0170 of the time as illustrated in figure 1 as its basic input in determining rain attenuation. A constant distribution is then assumed of attenuation due to rain to other percents of the time (formula in figure 2) as is shown by the solid curve in figure 2. How good this is can be surmised from figure 3 where the ratios of attenuation values derived for the rain distributions (Table 1) in the various CCIR geographical zones (the alternate zonal approach) are plotted. It can be seen that the fit is not bad for 0.001% to 0.1% of the time, but the formula gives a poor fit above 0.1 % of the time(Smith and Flock, 1995). In its favor is the fact that the attenuations are low for rain rates exceeded more than 0.1 % of the time.

The alternate approach of geographical zones, such as shown in Figure 4, each with its own rain distribution, has the unfortunate feature that a factor of 4 difference in rain rate can occur at zonal boundaries as illustrated in figure 5. Crane (1 993) has suggested that most rain attenuation models provide a prediction accuracy of about 30% which is compounded by a year-to-year natural variability of 20%.

The PARC (Propagation Analysis for Rain and Clear Air) Model . This model (Dissanayake, Allnutt and Haidara 1996) offers a somewhat different approach. propagation factors considered are

gaseous attenuation
cloud attenuation
melting layer attenuation
rain attenuation
tropospheric scintillations
low angle fading

PARC itself is a software package that contains all the above models and associated worldwide data bases necessary to do the calculations. Refractive and ionospheric effects are ignored. Special attention is given as to how to combine the different types of attenuation A relationship between rain rate and specific attenuation in the melting layer is derived. Rain attenuation is site specific and use is made of the Rice/Holmberg (19'73) rain model which requires average annual accumulation of rainfall and fraction of this rain arising from thunderstorm activity as input parameters. A comparison of prediction and measurement is made for paths with elevation angles of 5 degrees on up for 16 locations from around the world. A prediction accuracy of 20% is suggested for Earth-space paths from 4-35 GHz, not including the year-to-year variability.

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Report 1009-1 Propagation data for land mobile-satellite systems for frequencies above 100 Mhz, pp 536-549

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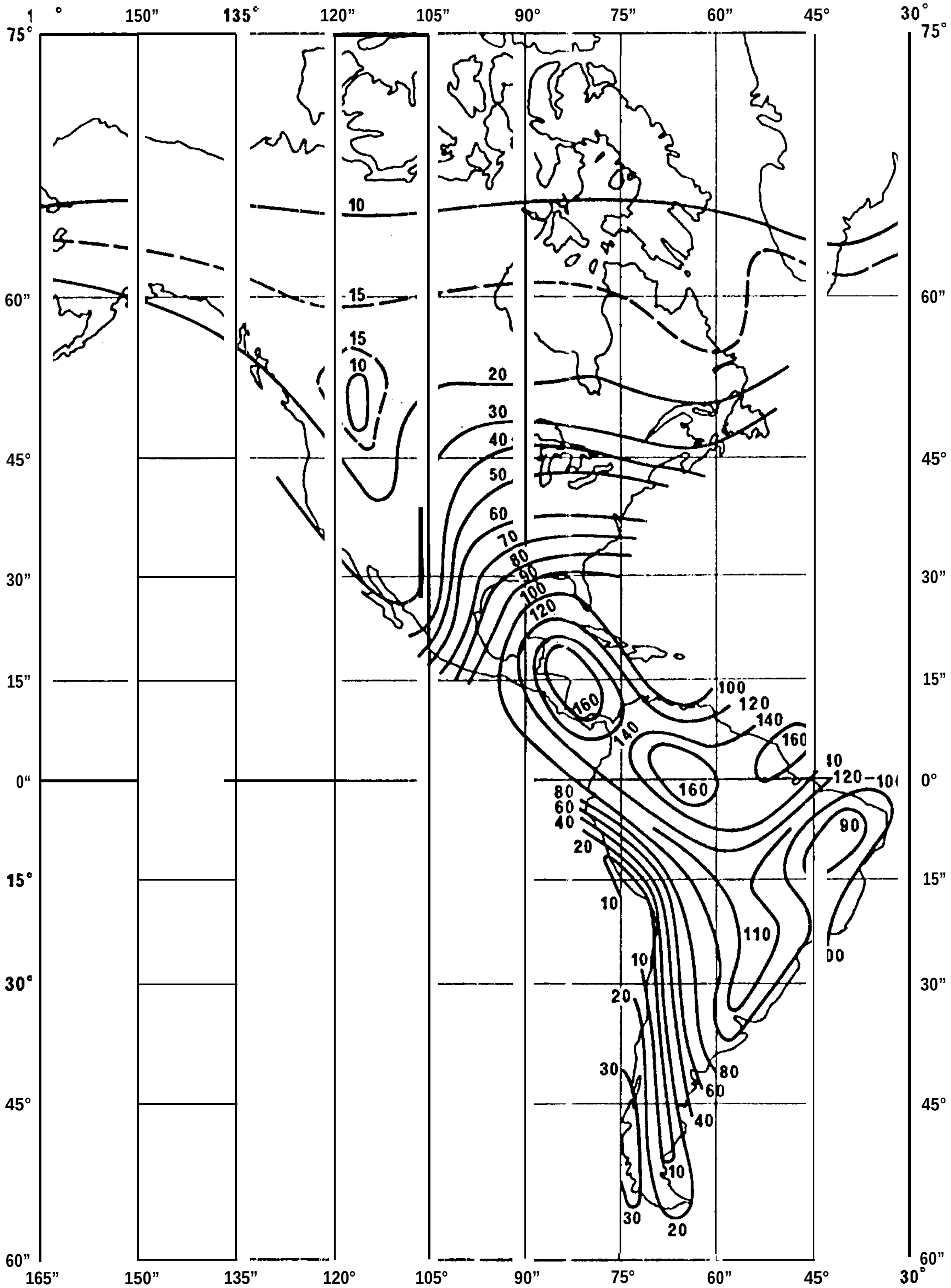

Figure 1. Rainfall contours for 0.01% of the time

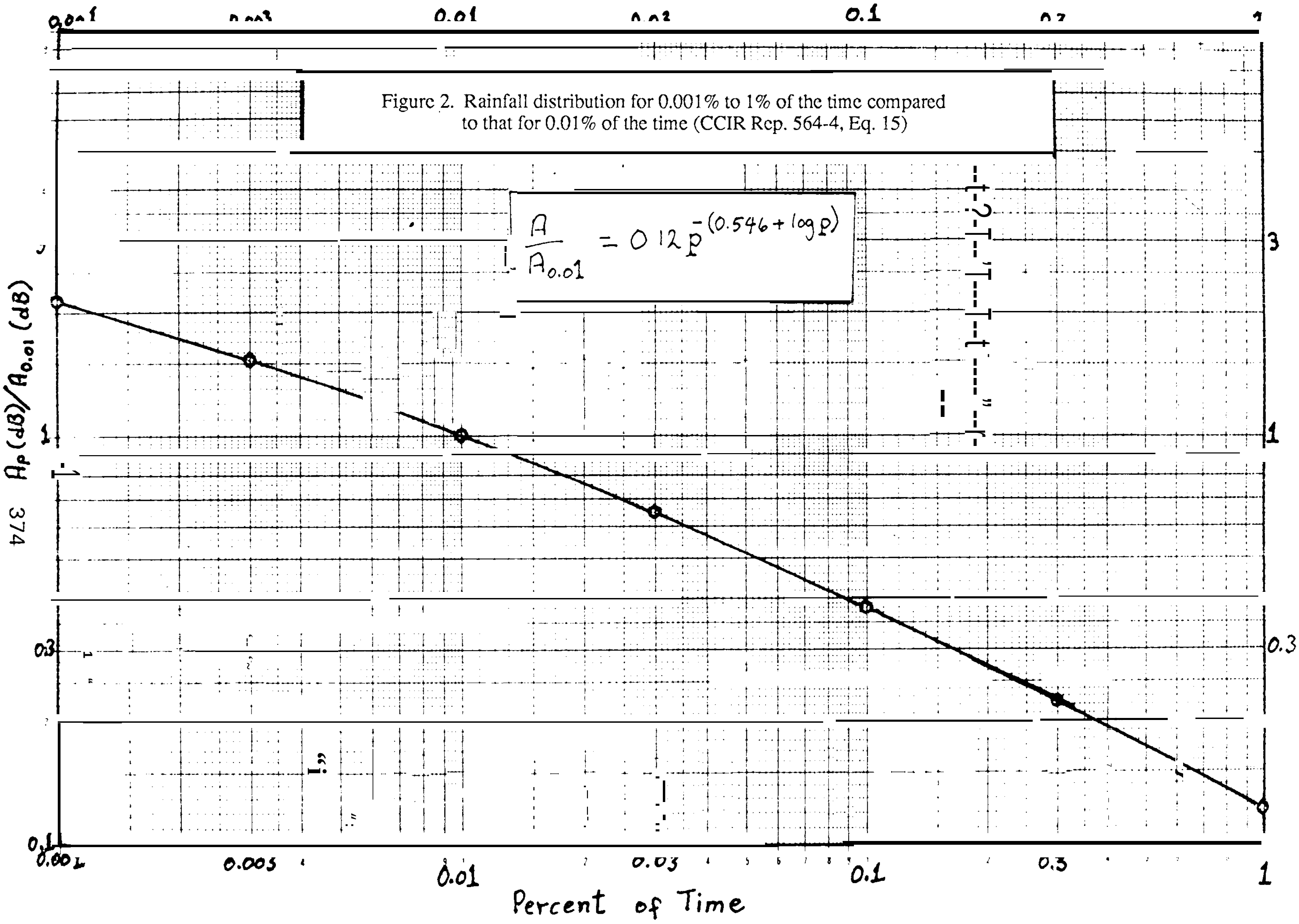

Figure 2. Rainfall distribution for 0.001% to 1% of the time compared to that for 0.01% of the time (CCIR Rep. 564-4, Eq. 15)

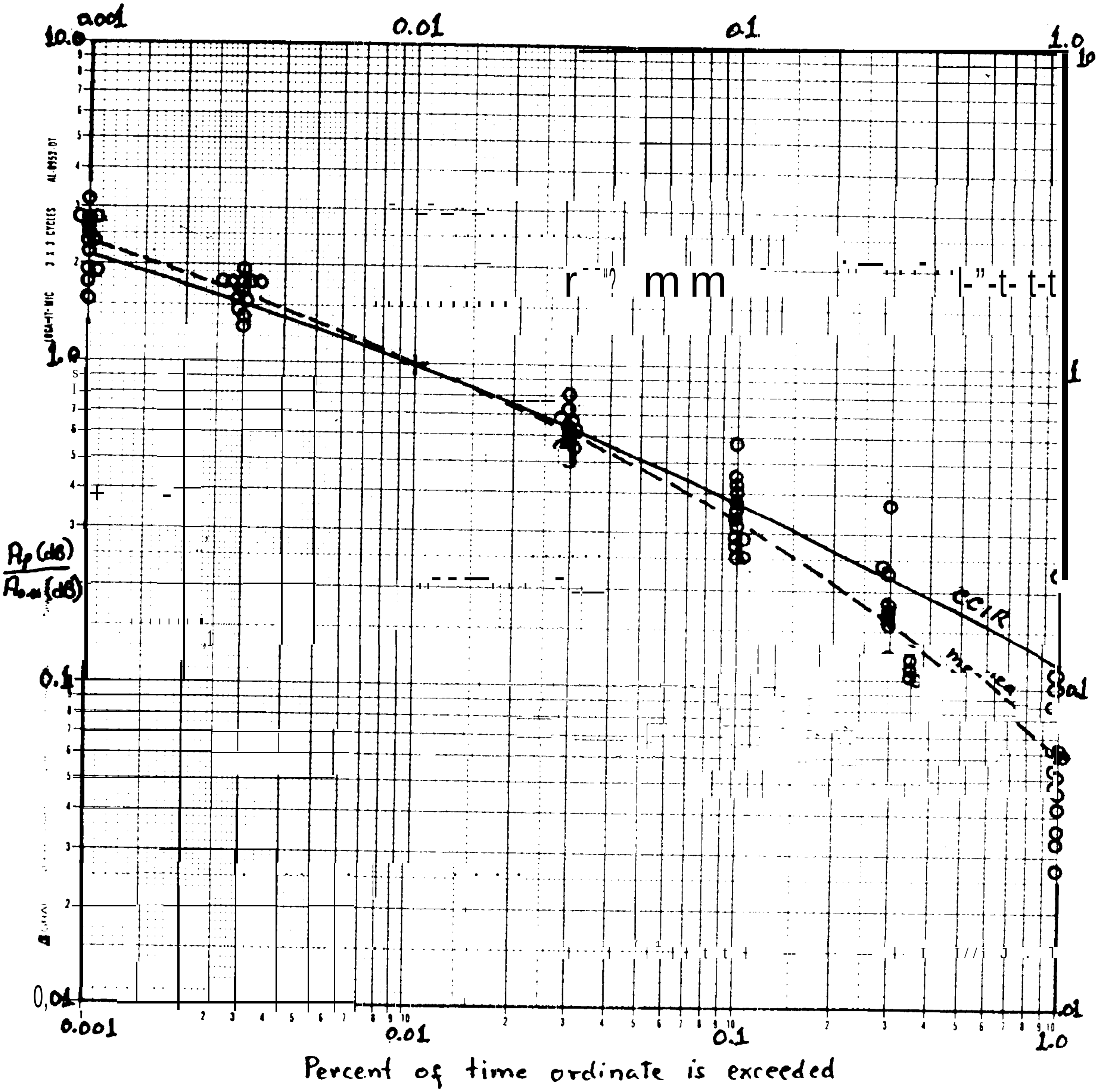

Figure 3. Comparison of the CCIR rainfall intensity distribution of Fig. 2 with the distributions given for rainfall zones in Table 1, Rep. 563-4

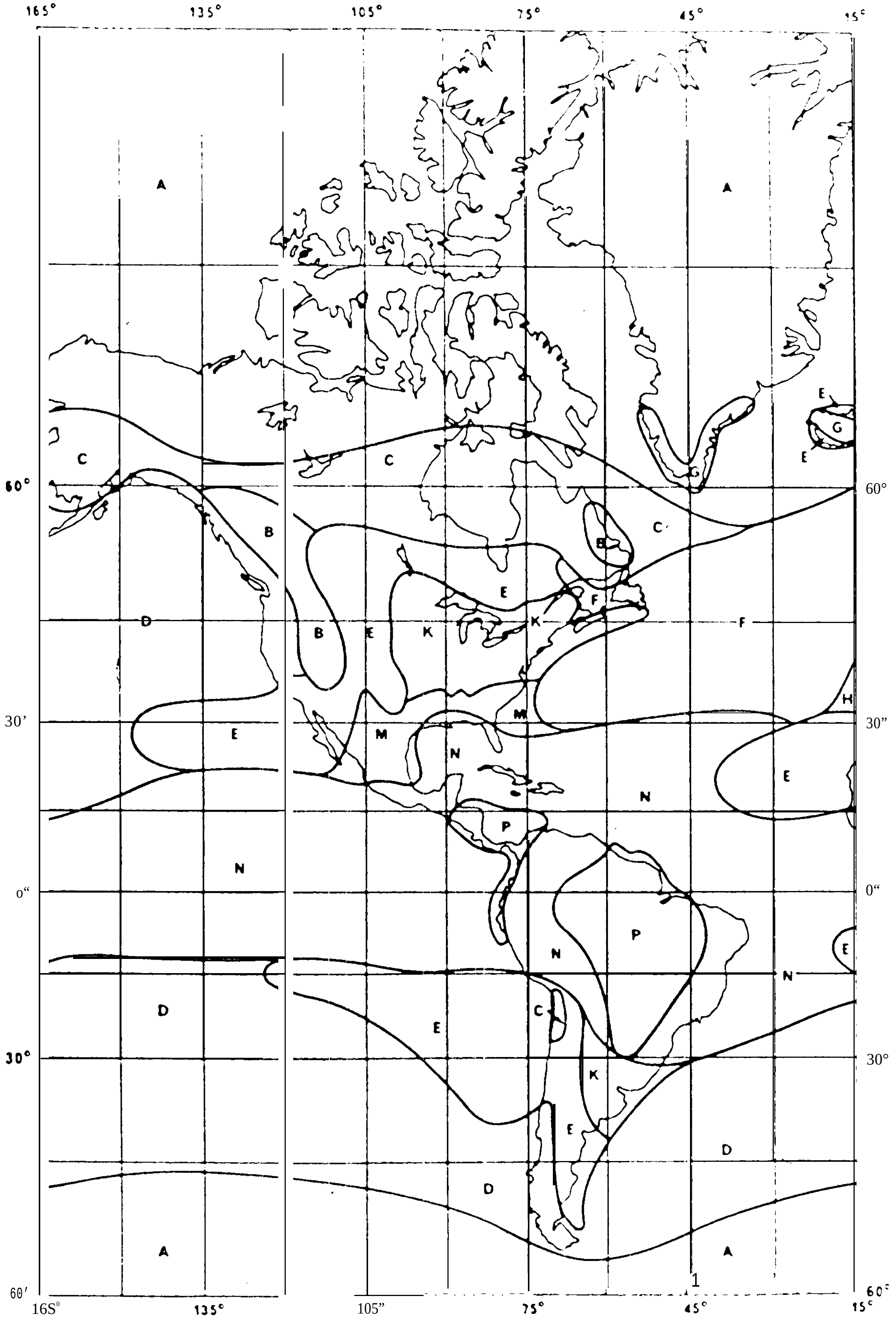

Figure 4. Rain zone map for the Americas
(CCIR Rep. 563-4, Fig 15)

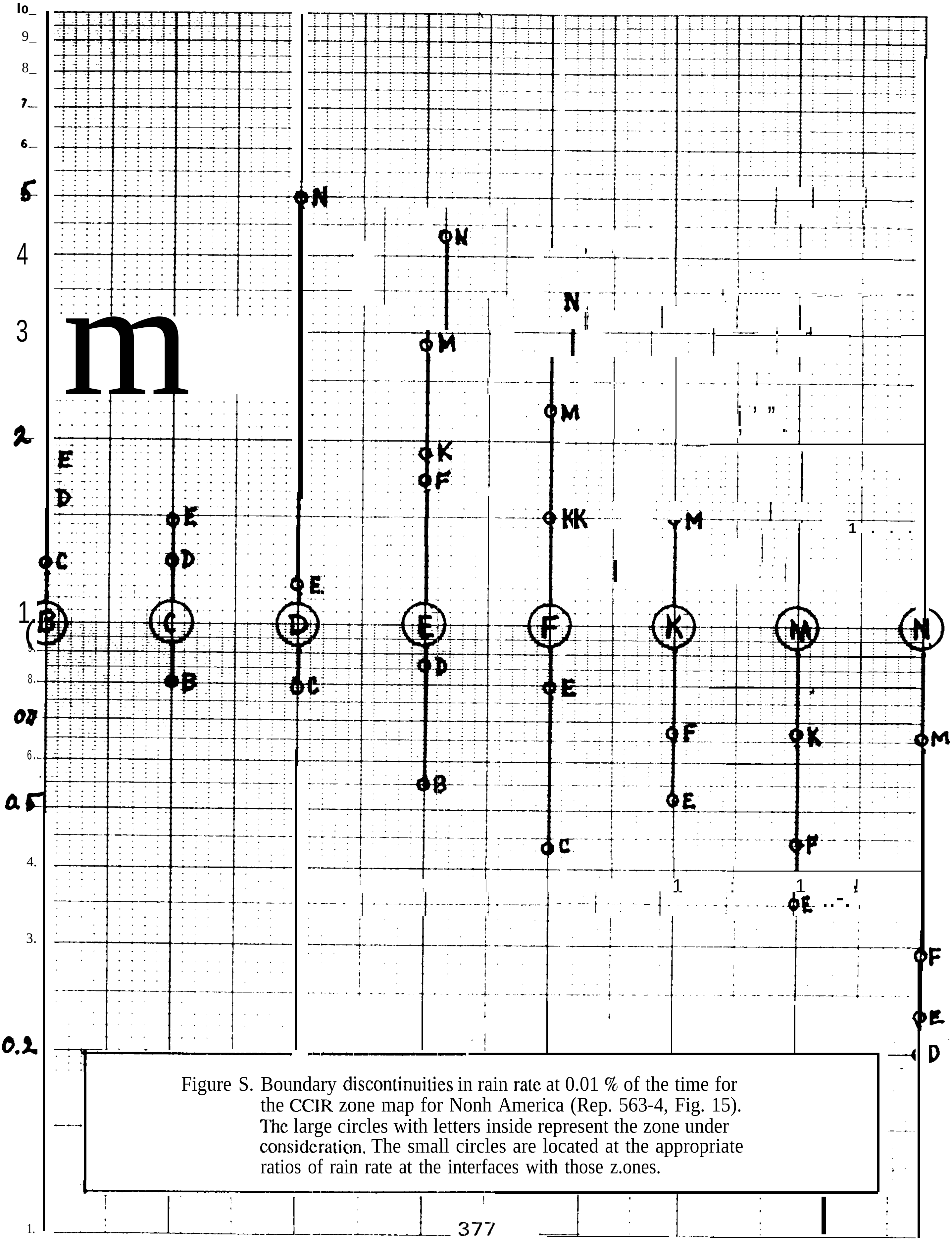

Figure S. Boundary discontinuities in rain rate at 0.01 % of the time for the CCIR zone map for Nonh America (Rep. 563-4, Fig. 15). The large circles with letters inside represent the zone under consideration. The small circles are located at the appropriate ratios of rain rate at the interfaces with those z.ones.

Table 1. Rain climatic zones, rainfall intensity exceeded (mm/h)
(Reference to Fig. 5)

Percentage Of time (%)	A	B	C	D	E	F	G	H	J	K	L	M	N	P
1.0	< 0.5	1	2	3	1	2	3	2	8	2	2	4	5	12
0.3	1	2	3	5	3	4	7	4	13	6	7	11	15	34
0.1	2	3	5	8	6	8	12	10	20	12	15	22	35	65
0.0?7	5	6	9	13	12	15	20	18	28	23	33	40	65	105
0.01	8	12	15	19	22	28	30	32	35	42	60	63	95	145
0.003	14	21	26	29	41	54	45	55	45	70	105	95	140	200
0,001	22	32	42	4?	70	78	65	83	55	100	150	120	180	250